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Fabrication of SiC–$SrTiO_3$-Nanoparticles-Doped PMMA/PEO Blend for Antibacterial and Radiation Shielding Fields

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This paper focuses on fabrication of new PMMA–PEO/SiC–$SrTiO_3$ nanostructures for the antibacterial and gamma-shielding actions with lightweight, flexibility and moderate price. The results of gamma-radiation shielding for PMMA–PEO/SiC–$SrTiO_3$ nanostructures show that the attenuation coefficient is enhanced by increasing the SiC–$SrTiO_3$-nanoparticles' content. The PMMA–PEO/SiC–$SrTiO_3$ nanostructures are tested for antibacterial application. The results demonstrate that the PMMA–PEO/SiC–$SrTiO_3$ nanostructures have good activity for antibacterial action. Therefore, new PMMA–PEO/SiC–$SrTiO_3$ nanostructures may be useful for the antibacterial and gamma-shielding applications.

Ця стаття стосується виготовлення нових наноструктур поліметилметакрилат–поліоксиетилен (ПММА–ПОЕ)/SiC–$SrTiO_3$ для протимікробної дії та захисту від гамма-випромінення з легкою вагою, гнучкістю та доступною ціною. Результати екранування гамма-випромінення для наноструктур ПММА–ПОЕ/SiC–$SrTiO_3$ показали, що коефіцієнт ослаблення підвищується за рахунок збільшення вмісту наночастинок SiC–$SrTiO_3$. Наноструктури ПММА–ПОЕ/SiC–$SrTiO_3$ було протестовано на протимікробне застосування. Результати показали, що наноструктури ПММА–ПОЕ/SiC–$SrTiO_3$ мають хорошу протимікробну дію. Таким чином, нові наноструктури ПММА–ПОЕ/SiC–$SrTiO_3$ можуть бути корисними для протимікробних і гамма-екранувальних застосувань.

Key words: SiC, $SrTiO_3$, PMMA–PEO, attenuation coefficient, antibacterial application.

Ключові слова: SiC, $SrTiO_3$, поліметилметакрилат–поліоксиетилен, коефіцієнт ослаблення, протимікробне застосування.

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1. INTRODUCTION

Radiant energy particles, such as alpha, beta, neutron particles, and electromagnetic wave emissions, are produced in a multitude of sectors as by-products including nuclear power plants, the medical devices, and space exploration [1–3]. Ionising radiation, including x-rays and γ-rays, is one of the most dangerous factors that could harm people's health. This behaviour is a result of ionising radiation's strong ability to penetrate human tissues and disrupt biological molecules that make up the human genome, such DNA [4]. From this point of view, the quality of the shielding material is viewed as the key to safeguarding against these dangerous radiations [5]. The idea behind shielding materials is based on how ionising radiation interacts with the electron density of the materials [6].

There are several different ways that gamma radiation interacts with shielding materials, including the photoelectric effect, Compton scattering, and pair creation. Each of these interactions depends on both the incident photon energy and the atomic number of the shielding materials [7]. Multiple factors, such as γ-rays' photon energy, density, and atomic weight of the shielding material, determine how shielding material attenuates γ-rays [8]. Generally, materials own both huge atomic number and density with a great stopping power providing high attenuation efficiency [9, 10]. Lead-free shielding materials offer a suitable, affordable, and eco-friendly replacement for traditional lead shielding and lead composite materials [11, 12]. Poly(methyl methacrylate) (PMMA), also referred to as 'acrylic', has superior optical clarity, strong abrasion resistance, hardness, and stiffness. Though it has lower mechanical strength and gamma ray shielding capacity than other metal shielding materials, it can be used with high-Z elements to enhance the mechanical and shielding capacity [13]. Additionally, PMMA is inexpensive, simple to work with it, and biocompatible, which accounts for its widespread use in dentistry [14]. Polyethylene oxide (PEO) is a semi-crystalline and linear polymer. Because polyethylene oxide is a linear polymer, a high degree of crystallinity is permitted by the regularity of the structural device. The cations of the metal salts can interact and form bonds with the polar group O in the chemical structure of PEO [15].

Due to its excellent mechanical, electrical, and thermal properties, such as fracture strength, large elastic modulus, stiffness and toughness, chemical stability, relatively low density and perfect thermal conductivity, as well as low thermal-expansion coefficient and high resistivity, silicon carbide (SiC) is one of the attractive filter ceramics for elevated temperature structural components [16].

There many studies on silicon and silicon carbide doped polymers to employ in various fields like optical, electronics, photonics and dielectric applications [17–23]. This work focuses on synthesis of new PMMA–PEO/$SiC–SrTiO_3$ nanostructures for antibacterial and gamma-shielding applications.

2. MATERIALS AND METHODS

The PMMA/PEO/SiC/$SrTiO_3$ nanostructures films were prepared using casting technique. The PMMA (75%) and PEO (25%) were dissolved 40 ml of chloroform with a magnetic stirrer for 1 hour to get a more uniform solution. The SiC/$SrTiO_3$ nanoparticles (NPs) with various weight percentages of 1.6, 3.2, 4.8, and 6.4 added to the PMMA/PEO solution. The distribution of SiC/$SrTiO_3$ NPs inside the PMMA/PEO blend was explored by optical microscope (OM) Nanostructured PMMA/PEO/SiC/$SrTiO_3$ are examined as antibacterial for gram-positive (*Staphylococcus aureus*) and gram-negative (*E. coli*) bacteria by using a disc diffusion method. The gamma-ray attenuation properties for various percentages of SiC/$SrTiO_3$ NPs have been examined. The samples were putted in front of a collimated beam hail from gamma-ray sources (Cs-137).

3. RESULTS AND DISCUSSION

Figure 1 displays the distribution of $SiC–SrTiO_3$ NPs *via* the PMMA/PEO matrix with various contents of $SiC–SrTiO_3$ NPs. At low concentration, the $SiC–SrTiO_3$ NPs are diffusing as a cluster. When the $SiC–SrTiO_3$ NPs percentages raise, the nanoparticles form paths connect inside the polymeric matrix [24–31].

Figures 2 and 3 show the antibacterial activity of the PMMA–PEO/$SiC–SrTiO_3$ nanostructures' films, which are tested against gram-negative (*Escherichia coli*) and gram-positive (*Staphylococcus*) bacteria. From these figures, the inhibition enhances with the increasing ratio of $SiC–SrTiO_3$ NPs. Reactive oxygen species (ROS), which are produced at various ratio of $SiC–SrTiO_3$ NPs, may be the cause of the antibacterial activity of PMMA–PEO/$SiC–SrTiO_3$ nanostructures.

At low ratio of nanoparticles, the interactions of particles with the cell wall of bacteria diminish, whereas the accumulation probability of particles rises at high percentage of particles. As a result, the effective surface to volume ratio of particles increases, and the resulting interaction between particles and the cell wall of bacteria reduces. It is notably from the result that the antibacterial activity of the samples was stronger against gram-negative bacteria (*Esche-*

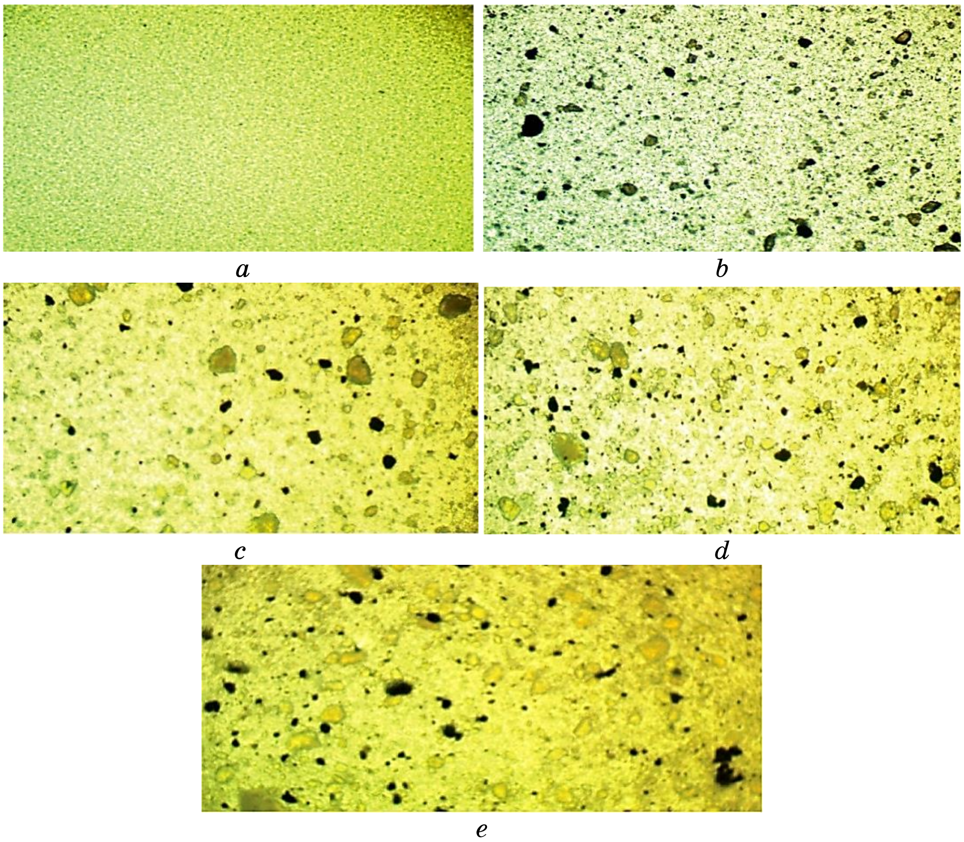

Fig. 1. Optical microscope images (×10) for PMMA–PEO–SiC–$SrTiO_3$ nanostructures: (*a*) pure; (*b*) 1.6 wt.% SiC–$SrTiO_3$ NPs; (*c*) 3.2 wt.% SiC–$SrTiO_3$ NPs; (*d*) 4.8 wt.% SiC–$SrTiO_3$ NPs; (*e*) 6.4 wt.% SiC–$SrTiO_3$ NPs.

richia coli) than gram-positive bacteria (*Staphylococcus*) on nanoparticles. This is because the gram-positive bacteria possess a thick cell wall contains several peptidoglycan layers. On the other hand, gram-negative bacteria own a comparatively thin cell wall formed up some layers of peptidoglycan [32–41].

Figure 4 depicts the change of ratio (N/N_0) for PMMA/PEO with varied concentrations of SiC–$SrTiO_3$ NPs. The transmission radiation reduced with a rise in the SiC–$SrTiO_3$-nanoparticles' loading. This takes place as a result of a rise in attenuation radiation.

Figure 5 shows the behaviour of attenuation coefficient for PMMA–PEO blend with different ratios of SiC–$SrTiO_3$ NPs. The attenuation coefficients rise as the ratio of nanoparticles rises because nanostructures' shielding materials either absorb or reflect gamma-radiation [42–45].

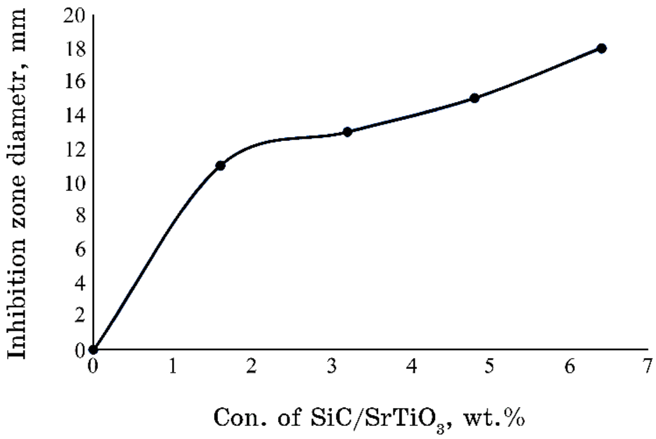

Fig. 2. Inhibition zone diameter of PMMA/PEO/SiC/$SrTiO_3$ nanostructures against *Escherichia coli*.

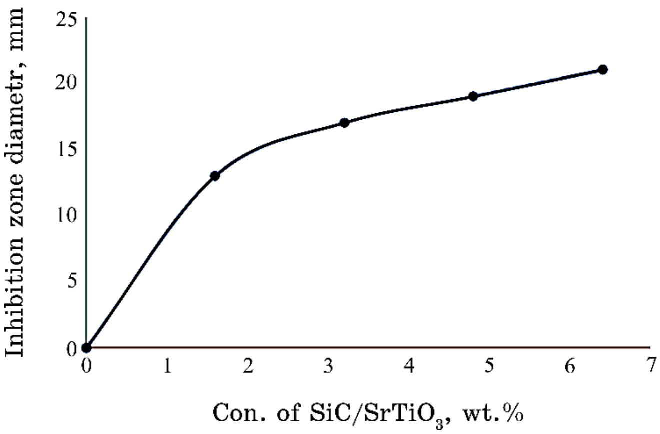

Fig. 3. Inhibition zone diameter of PMMA/PEO/SiC/$SrTiO_3$ nanostructures against *Staphylococcus* bacterium.

4. CONCLUSION

This article involves fabrication of PMMA–PEO/SiC–$SrTiO_3$ nanostructures with lightweight and flexible, which have good gamma-ray attenuation coefficients and high antibacterial activity. The results of gamma-radiation shielding for PMMA–PEO/SiC–$SrTiO_3$ nanostructures showed that the attenuation coefficient is enhanced by increasing the SiC–$SrTiO_3$-NPs' content. The PMMA–PEO/SiC–$SrTiO_3$ nanostructures were tested for antibacterial application. The results demonstrated the PMMA–PEO/SiC–$SrTiO_3$ nanostructures have good antibacterial activity. Therefore, new

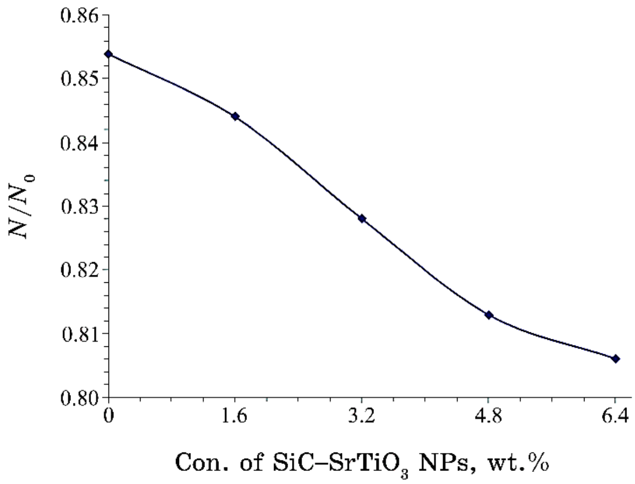

Fig. 4. Variance of (N/N_0) for PMMA/PEO with different concentrations of SiC–$SrTiO_3$ NPs.

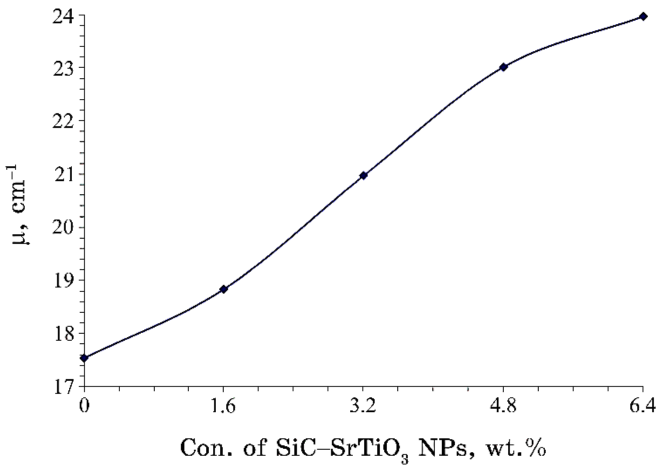

Fig. 5. Variance of attenuation coefficients of gamma-radiation for PMMA/PEO blends with different concentrations of SiC–$SrTiO_3$ NPs.

PMMA–PEO/SiC–$SrTiO_3$ nanostructures may be useful in antibacterial and gamma-shielding applications.

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